JWST Observatory Overview

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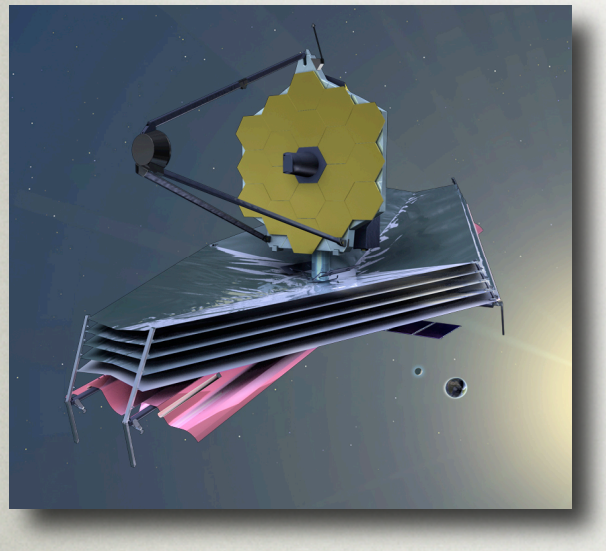
SPIE: 6265-22

JWST: Quick Facts

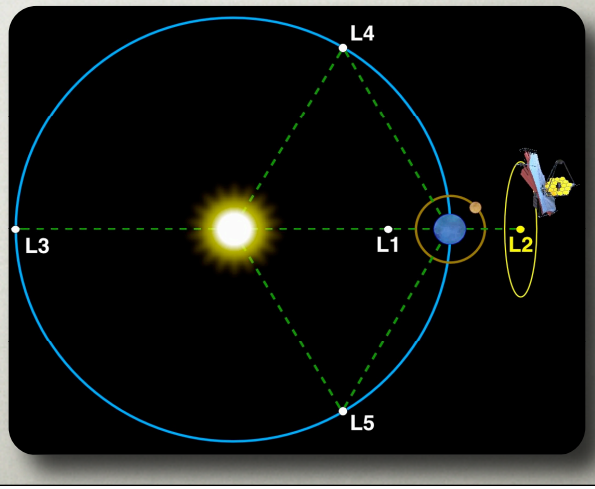


Organization

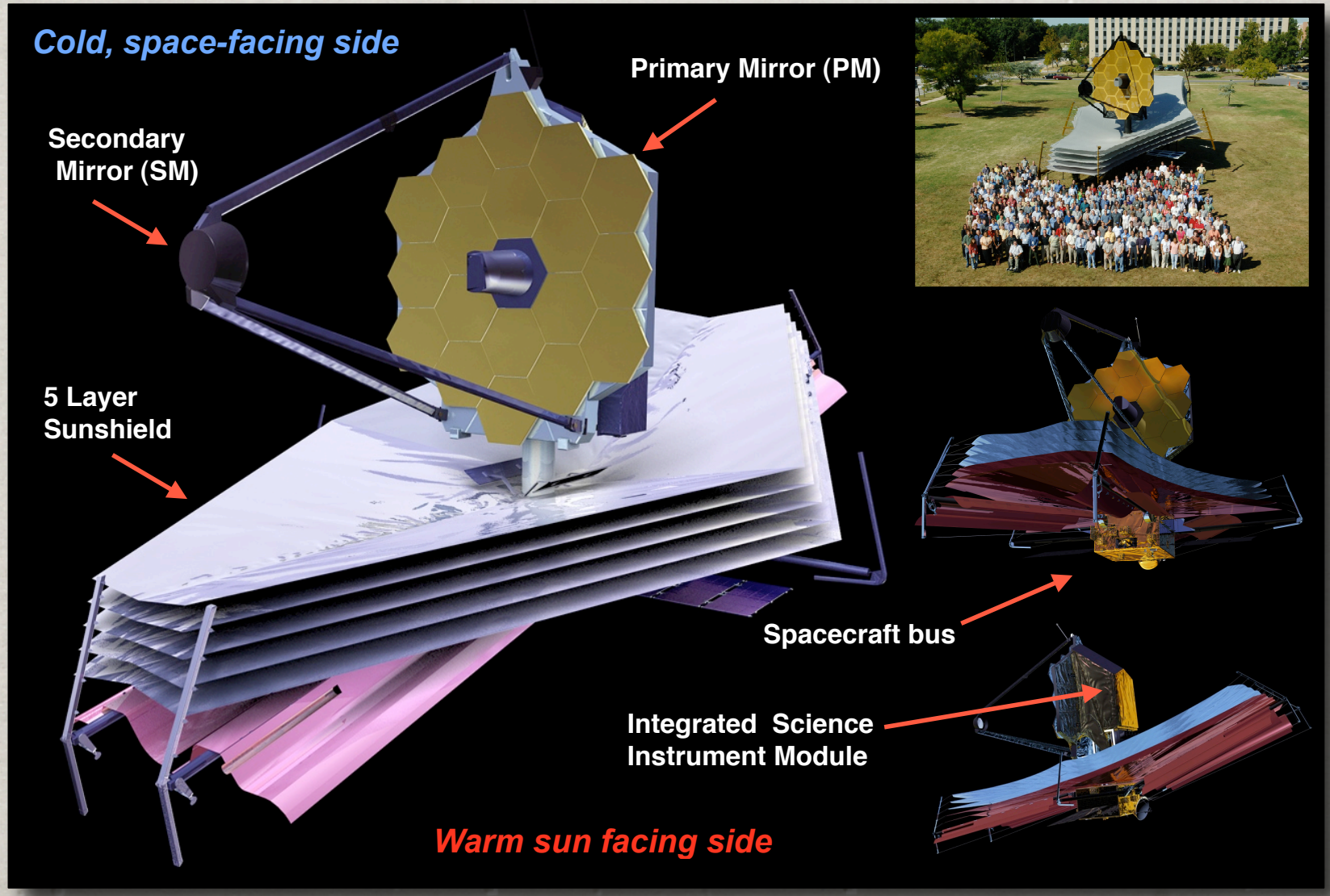
Mission Lead: Goddard Space Flight Center
International collaboration with ESA & CSA
Prime Contractor: Northrop Grumman Space Technology
Instruments:
Near Infrared Camera (NIRCam) – Univ. of Arizona
Near Infrared Spectrograph (NIRSpec) – ESA
Mid-Infrared Instrument (MIRI) – JPL/ESA
Fine Guidance Sensor (FGS) – CSA
Operations: Space Telescope Science Institute (STScI)

Description

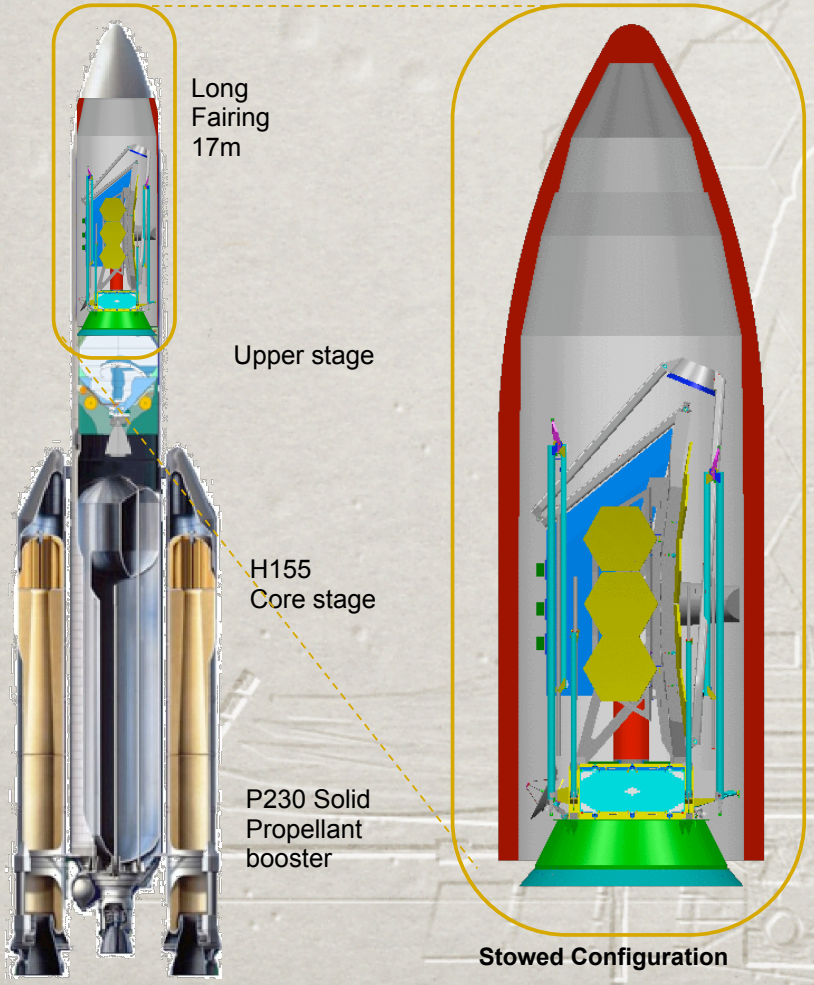
- Deployable cryogenic telescope
  - 6.5 meter Φ, segmented adjustable primary mirror
- Launch on an ESA-supplied Ariane 5 to Sun-Earth L2
- 5-year science mission (10-year goal): launch 2013



JWST Architecture

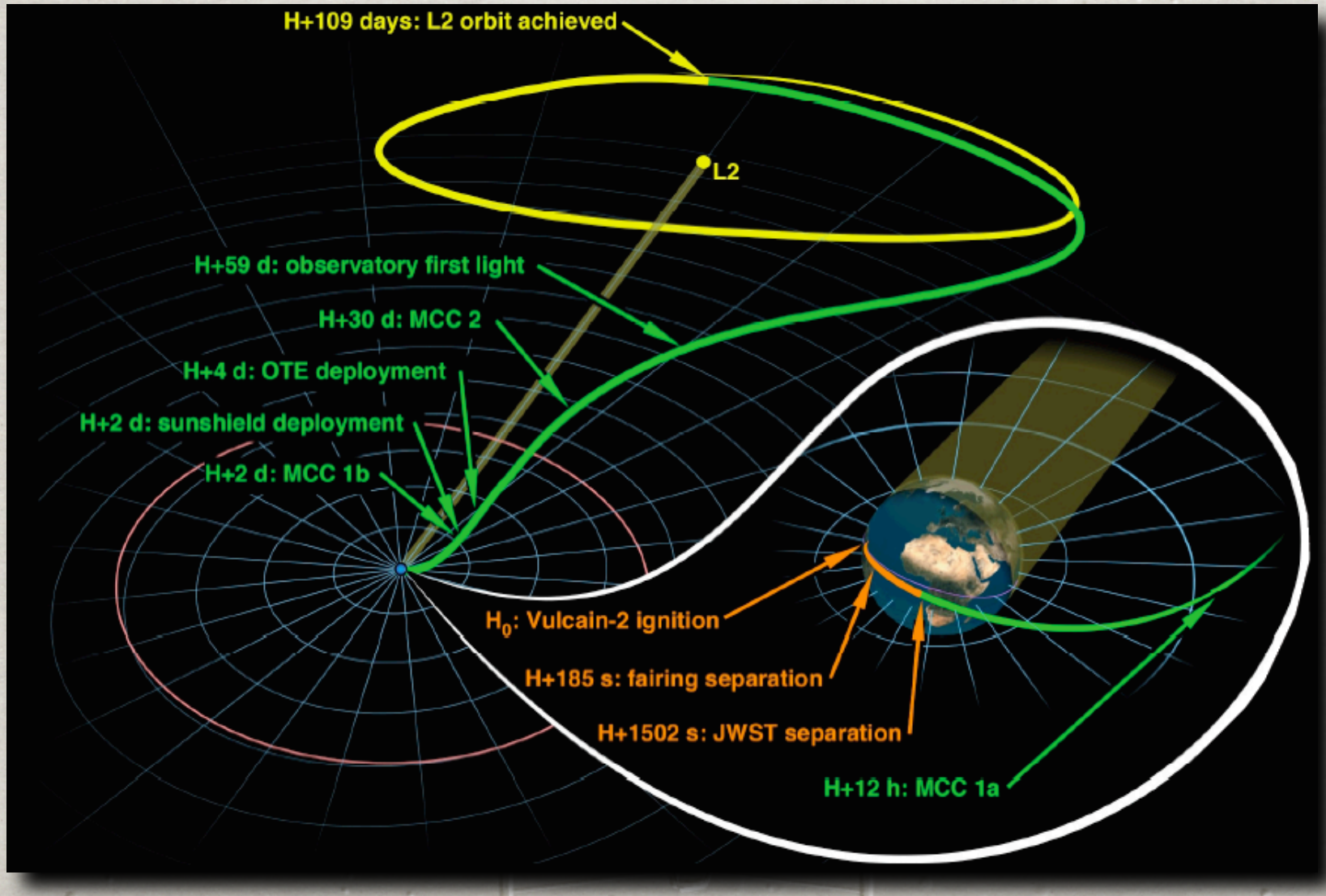


Launch Configuration



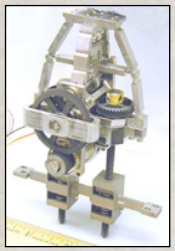
- JWST is folded into stowed position to fit into the payload fairing of the Ariane V launch vehicle

Launch to L2 Orbit

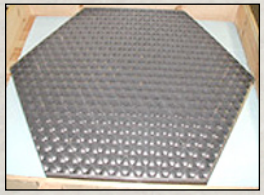


Early Technology Investment

Mirrors

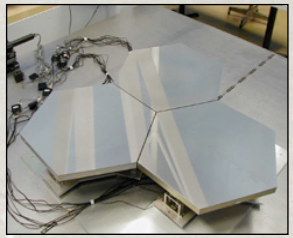


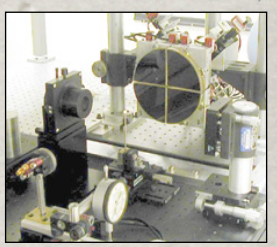
AMSD



SBMD

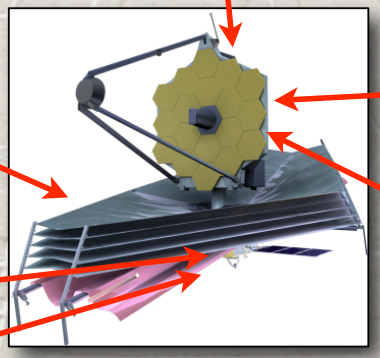
Mirror System





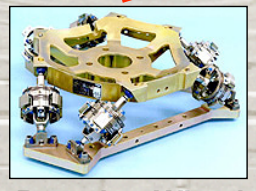
Wavefront Sensing and Control, Mirror Phasing

Half-Scale Sunshield Model

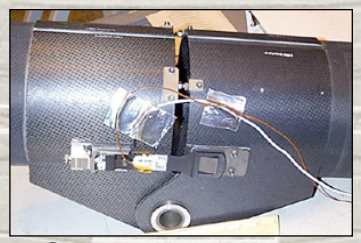


Cryogenic Deployable Optical Telescope Assembly (**DOTA**)

1 Hz OTE Isolators

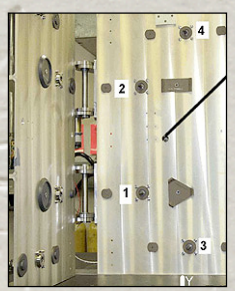


Reaction Wheel Isolators



Secondary Mirror Structure Hinges

Primary Mirror Structure Hinges and Latches

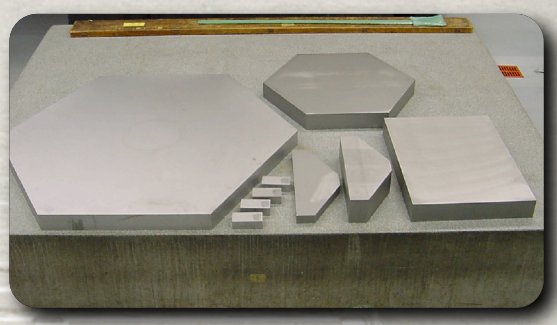


Mirror Manufacturing

Grind

Polish

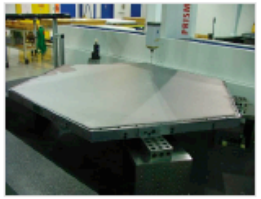
Cryo. Test

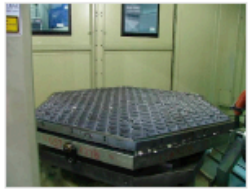


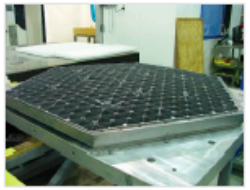
Mirror blanks HIPed at Brush Wellman

PM Segments well into Production

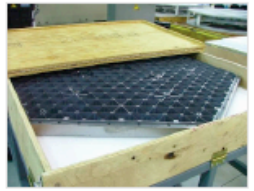
PMSA #1 (EDU-A / A1)

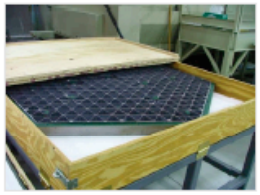

PMSA #2 (6 / B2)

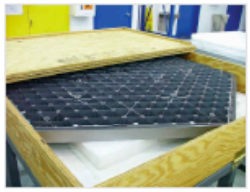

PMSA #3 (4 / C1)


PMSA #4 (5 / A2)

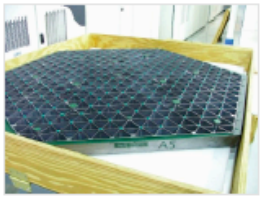

COMPLETE!!
PMSA #5 (3 / B1)


PMSA #6 (7 / C2)

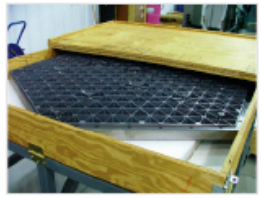

PMSA #7 (13 / A4)

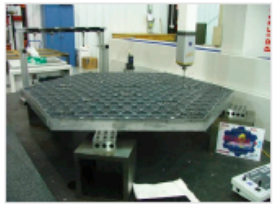

PMSA #8 (11 / B3)


PMSA #9 (12 / C3)

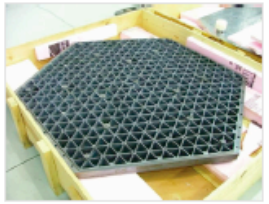

PMSA #10 (16 / A5)


PMSA #11 (17 / B5)


PMSA #12 (15 / C4)

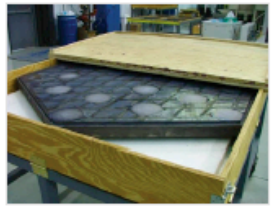

PMSA #13 (8 / A3)


PMSA #14 (20 / B6)

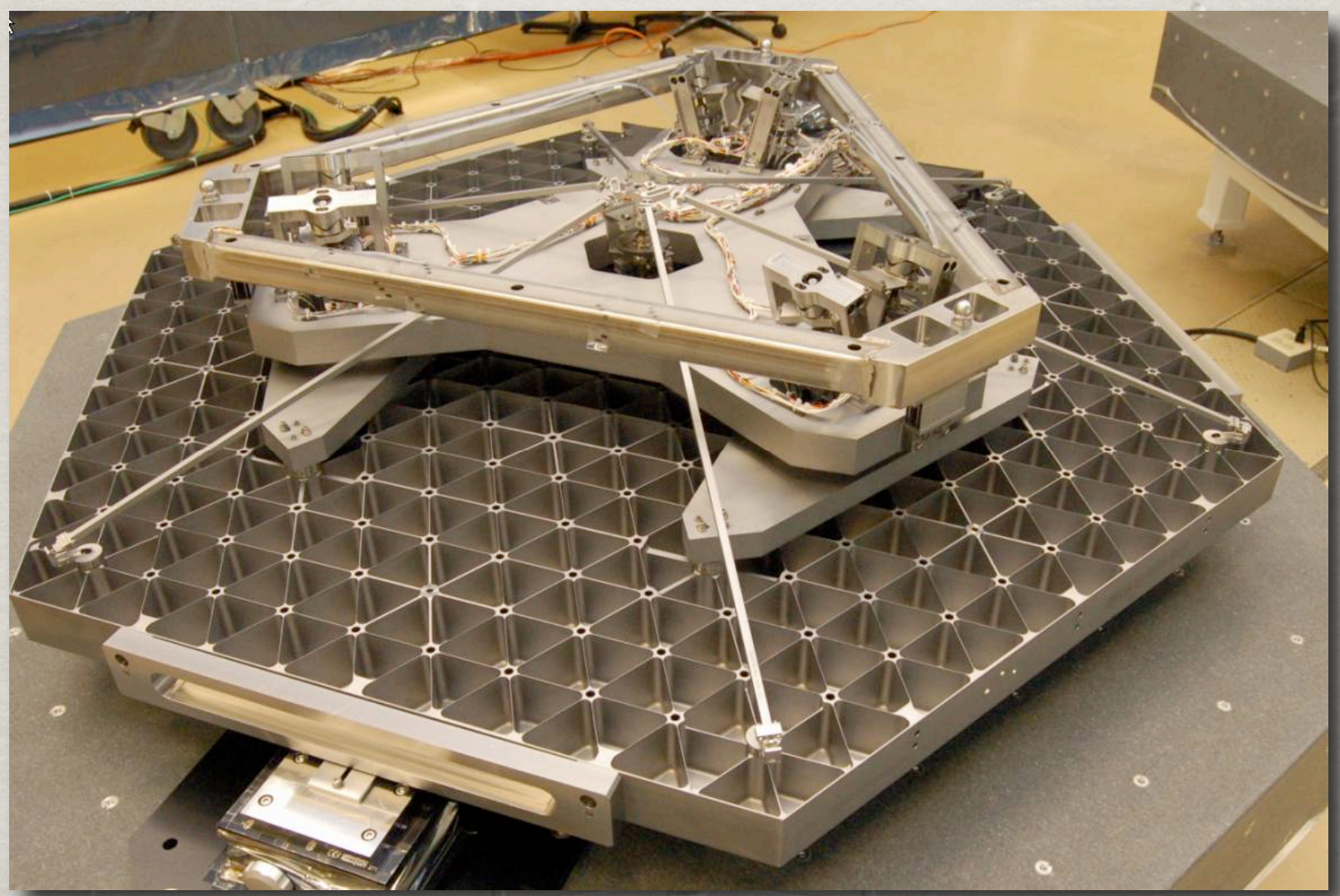

PMSA #15 (18 / C5)


PMSA #16 (19 / A6)


PMSA #17 (22 / B7)


PMSA #18 (21 / C6)

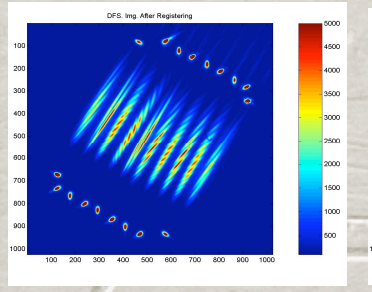
Flight Mirror + Actuator Assembly



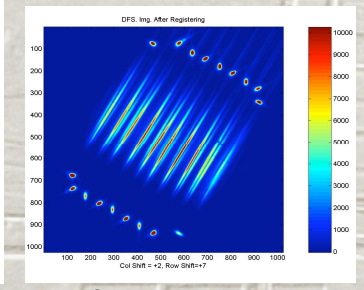
JWST Backplane Test

Wavefront Sensing

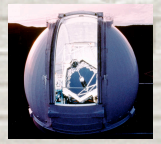
- **Wavefront Sensing and Control (WFSC) provides the algorithms used to align OTE**
- **WFSC testbeds at the Goddard Space Flight Center (the Wavefront Control Testbed) and at Ball were used to develop JWST-specific technologies to TRL 4/5**
- **Demonstrated the specific coarse phasing portion to be used on JWST on the inner 18 segments of the Keck Telescope**
- **WFSC Testbed Telescope is a 1/6th scale, fully functional model of the JWST telescope**

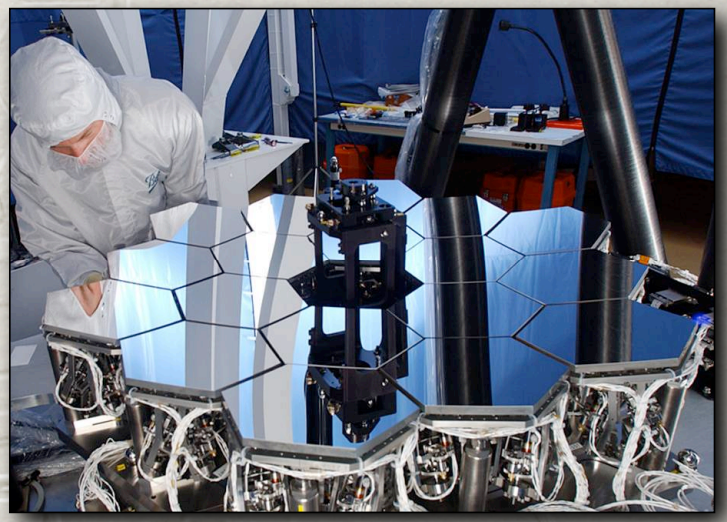


Initial errors
Max piston error=19 μm
Rms=5 microns

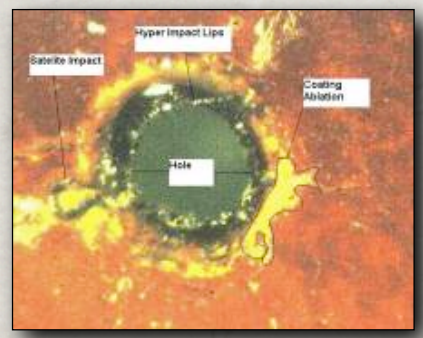


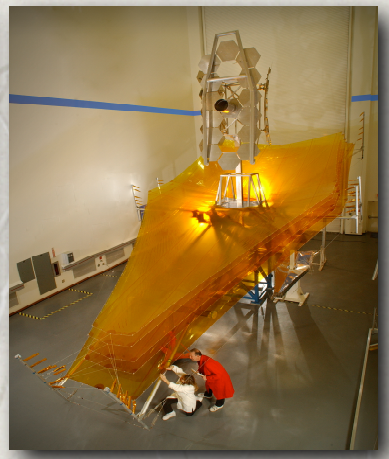
After correction
Max piston error=0.66 μm
Rms=0.18 microns





Sunshield





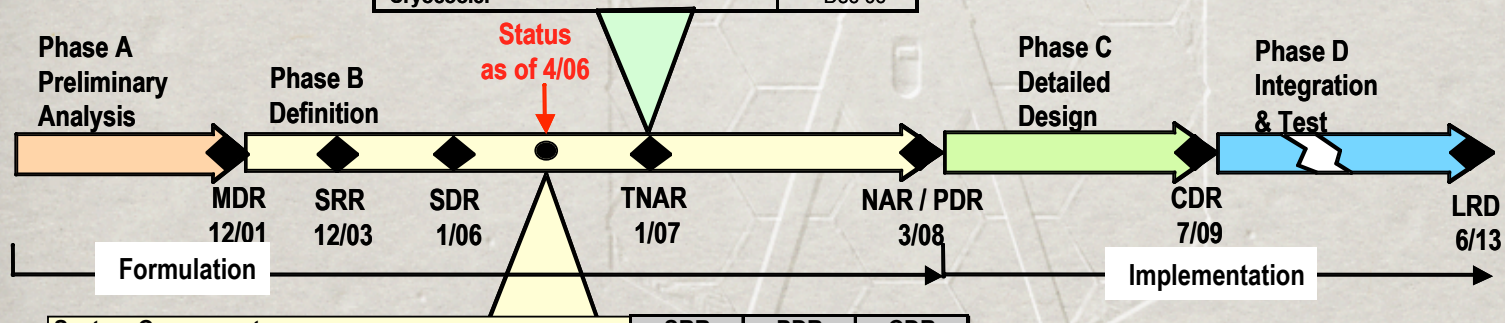
- Sunshield concept design review (CODR) successfully completed
- Subscale testbeds being used to evaluate deployments
- NGST has significant experience with deployables: 2200 successful mechanism deployments

JWST Schedule

Technology Development Hardware	TRL-6 Status
NIR Infrared Detectors	Complete
Sunshield Materials	Complete
Mid Infrared Detectors	May-06
Light Weight Cryogenic Mirrors	Jun-06
Microshutter Arrays	Aug-06
Cryogenic Detector Readout ASICs	Aug-06
Cryogenic Heat Switches	Sep-06
Large Precision Cryogenic Structure	Nov-06
Wavefront Sensing and Control	Dec-06
Cryocooler	Dec-06

Key

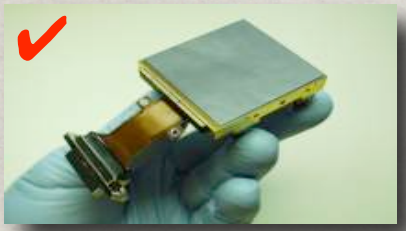
- SDR - System Design review
- TNAR - Technology Non-Advocate review
- NAR - Non-Advocate Review
- PDR - Preliminary Design Review
- CDR - Critical Design Review
- LRD - Launch Readiness Review



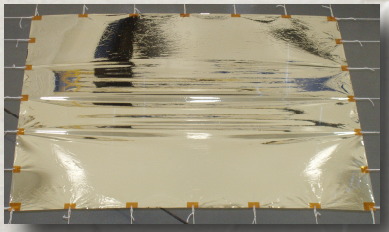
System Components	SRR	PDR	CDR
System	Dec-03	Mar-08	Jul-09
Observatory	Dec-03	Mar-08	Jul-09
Optical Telescope Element (OTE)	Mar-03	Apr-07	Apr-08
Primary Mirror Segments	Jan-04	Jul-04	Sep-05
Backplane Assembly	Aug-04	Jun-06	Apr-07
Integrated Science Instrument Module (ISIM)	Mar-04	Oct-06	Dec-08
Near-Infrared Camera (NIRCam)	Nov-03	Oct-04	May-06
Near-Infrared Spectrograph (NIRSpec)	Oct-04	Dec-05	Jan-08
MIRI Optics Systems	Mar-04	Dec-04	Oct-06
MIRI Cooling System	Feb-07	May-07	Mar-08
Fine Guidance Sensor (FGS)	Apr-04	May-05	Nov-06
Tunable Filter (TF)	Apr-04	May-05	Mar-07
ISIM Flight Software (FSW)	May-04	Feb-06	Mar-07
Spacecraft Bus	Oct-04	Sep-08	Sep-09
Sunshield	Oct-04	Jan-07	Sep-09
Observatory FSW	May-05	Sep-07	Oct-08
Ground Segment	Oct-04	Dec-08	Dec-09

Pending
Completed

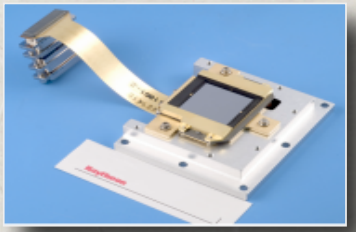
Technology Milestones



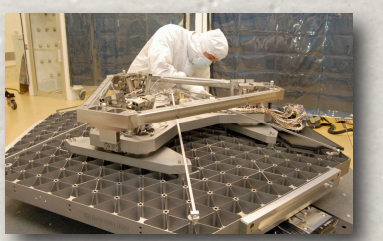
Near Infrared Detectors
April 2006



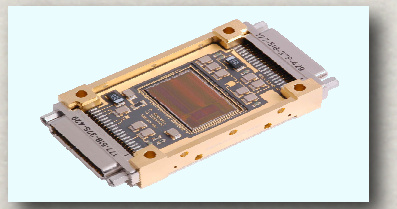
Near Infrared Detectors
April 2006



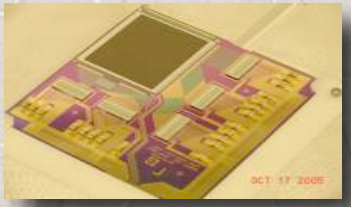
Near Infrared Detectors
April 2006



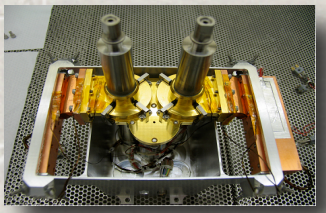
Primary Mirror
Segment Assembly
June 2006



Cryo ASICs
August 2006

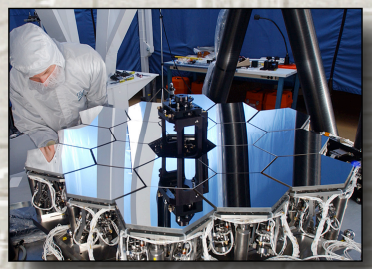


Microshutter Arrays
August 2006

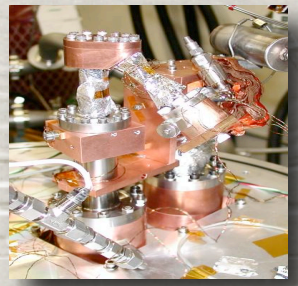


Heat Switches
September 2006

Large Precision Cryogenic Structure
November 2006



Wavefront Sensing & Control
December 2006



Cryocooler
December 2006

JWST Replan

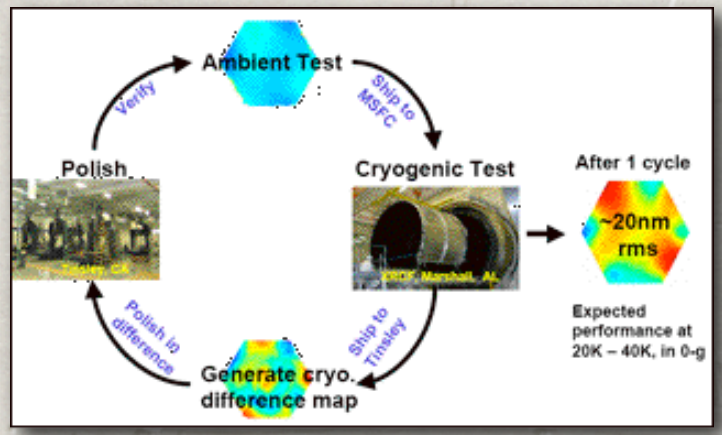
Courtesy: Eric Smith, NASA/HQ

- **Science Mission Directorate investigates descopes, commissions independent Science Assessment Team (SAT), directs replanning - Apr 05**
- **PA&E commissions independent special review - May 05**
  - Interim special Agency Program Management Council (APMC) meetings
- **Replanning completed - Mar 06**
- **Special Review completed - Apr 06**
  - Final special APMC meeting - Apr 06

SAT Committee: I

Emphasize wavelengths ≥ 1.7 μm
- Eliminate image quality specs at 1μm

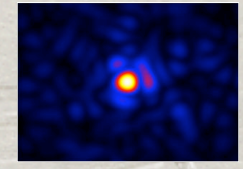
- Reduces need for extra cryo-polishing cycles



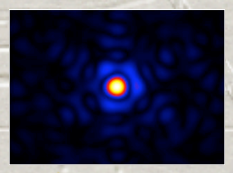
- Relax requirements for backplane stability

Relaxes Optical Error Budgets

Diffraction limited @ 2µm



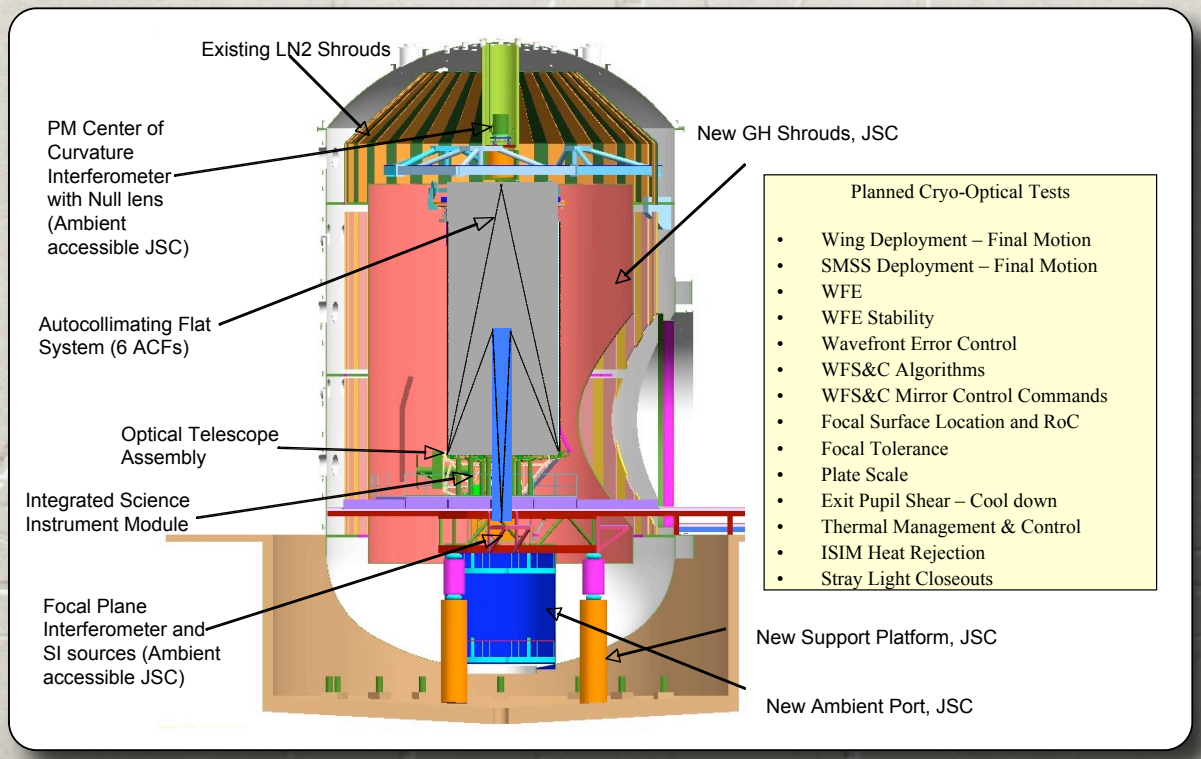
1 µm



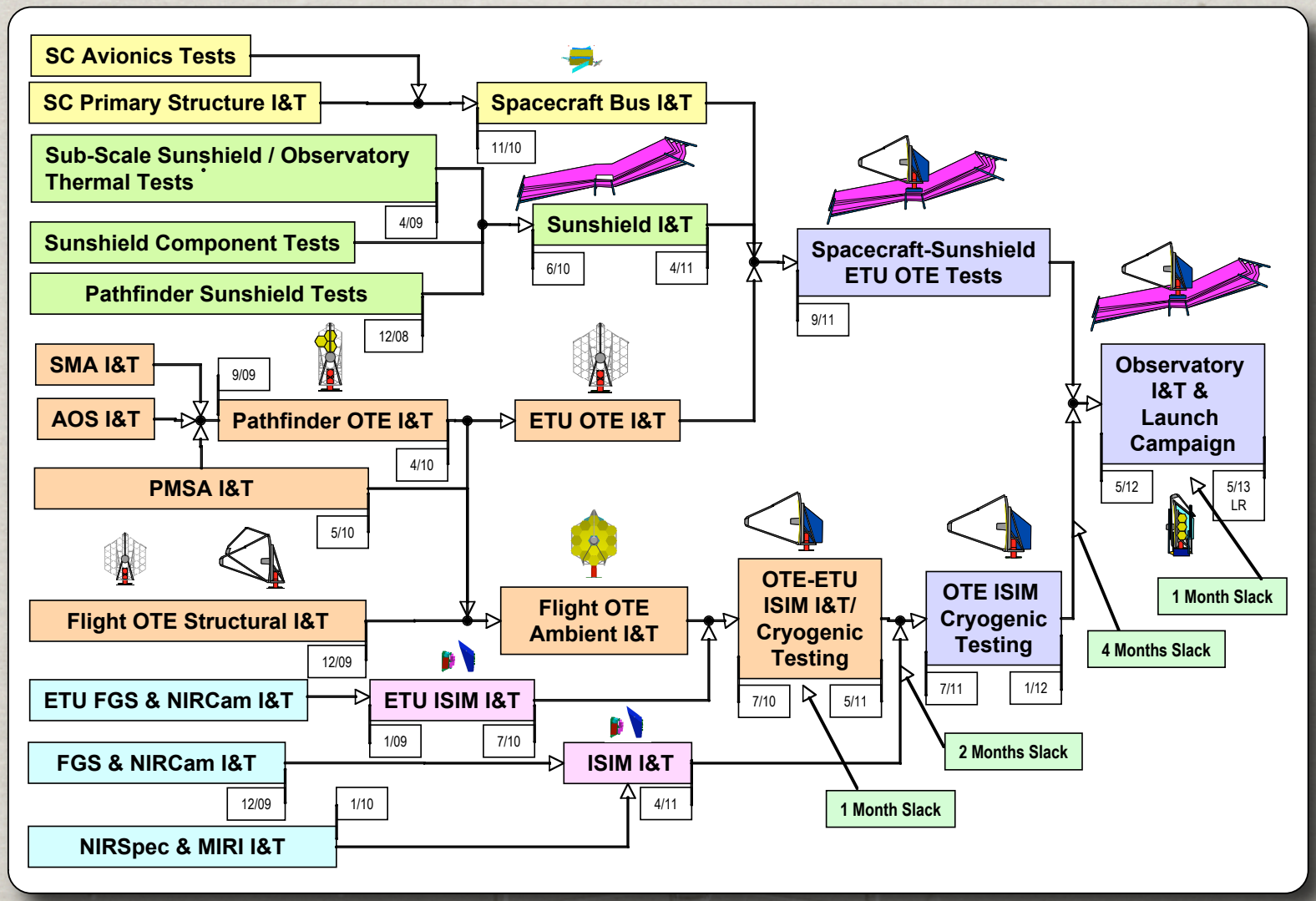
2 µm

SAT Committee: II

- Endorse further I & T simplifications exploiting JWST's active optics control
- More frequent telescope alignments (<30 days)
- Relax requirements, if required to enable "Cup-Up" cryogenic testing



JWST Integration and Test Plan



JWST Status: Summary

- **Rebaselining activities following re-plan are complete**
  - Results presented to the Agency Program Management Council (PMC)

- **Approval to use the European Space Agency (ESA) provided Ariane 5 launch vehicle was received in December 2005**

- **Continuing to make excellent progress towards the June 2013 Launch Readiness Date (LRD)**
  - **Successful System Definition Review (SDR) in January 2006**
  - **Flight Primary Mirror (PM) production is on schedule; all 18 flight primary mirrors have started or completed the machining process; the first was completed last month; 5 more will be completed in June**
    - **PM Engineering Development Unit (EDU) is being polished at Tinsley**
  - **Instrument Critical Design Reviews (CDRs) have started**
  - **All mission critical technologies are on schedule to be demonstrated in a space like environment by the end of 2006**

JWST is impacting other Programs

- Current fiscal pressure within Astrophysics Division has multiple causes
  - Removal of ~$3B from Science Mission Directorate funding for other higher priority programs
    - Astrophysics Division lost $382M in FY07-FY011 budget
  - Congressionally directed spending outside planned program
    - Approximately 4% of SMD budget directed to Congressionally mandated activities (~$200M)
  - Delay in HST SM4
    - Original SM4 date, 2002, last budgeted launch date (*i.e.*, before FY07 budget) Nov 2004
  - Program cost increases/other problems (launch ordered)
    - SOFIA, GLAST, *Kepler*, JWST

Courtesy: Eric Smith, NASA/HQ

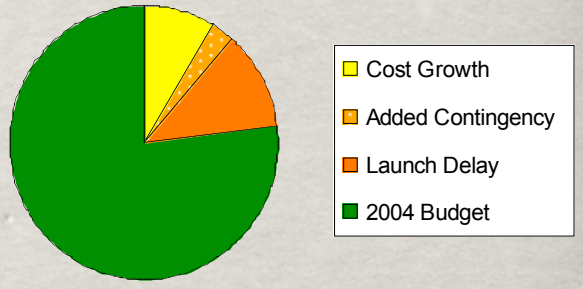
Fast Financial Facts

- Current Status as of April 06 (RY$):
  - Remaining cost to 2013 launch: ~$2.5B
    - Sunken cost through end of FY06: $1.0B
      - Includes $230M early technology development investment
- Operations (RY$):
  - Direct support to university and other institution users: $25M/yr
    - Ten year operations and data analysis: $890M

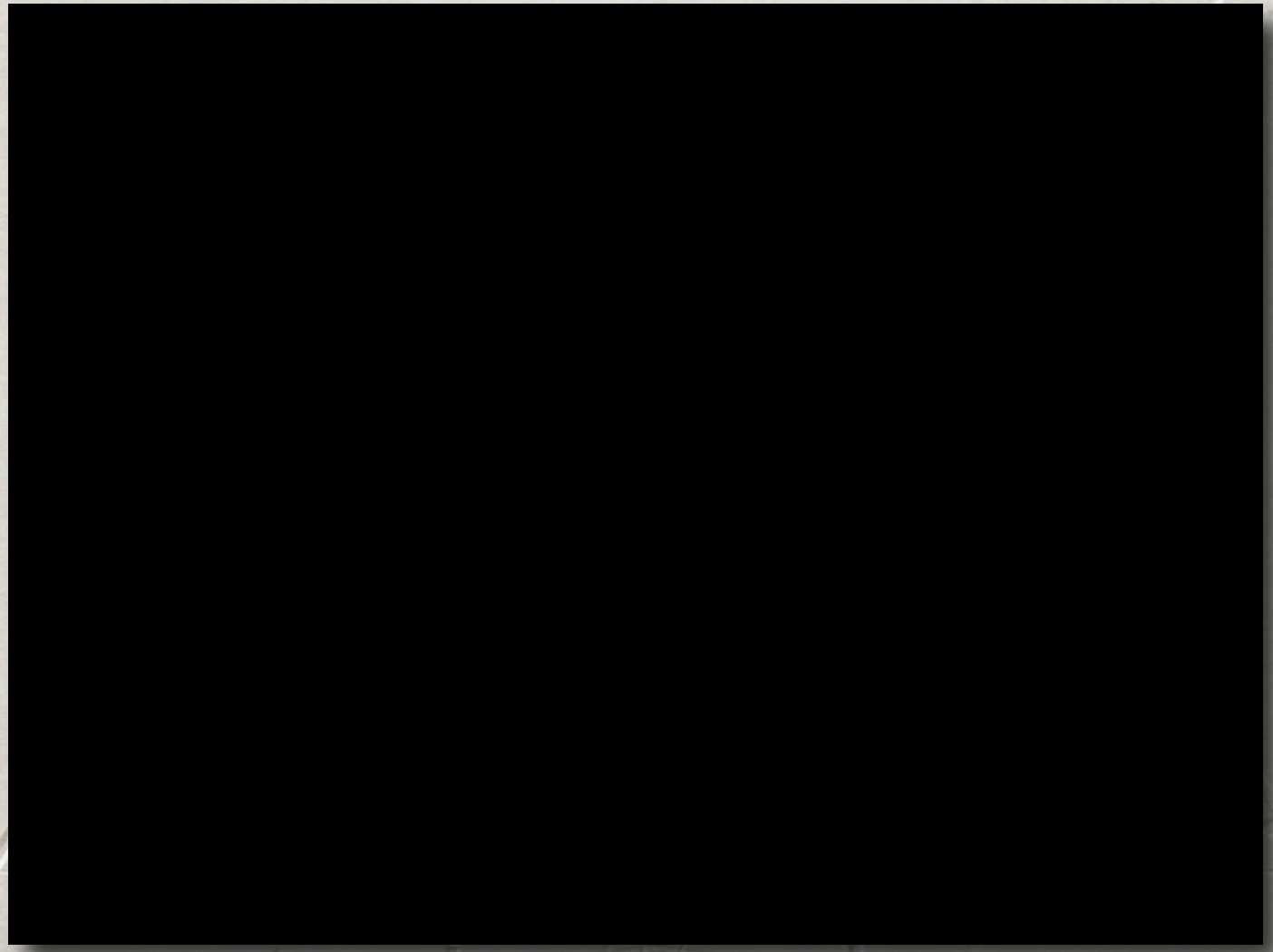
Mission Comparison ($B)			
	HST	Chandra	JWST (Projected)
Phase A-D	4.1 (FY06)	3.4 (FY06)	3.3 (FY06)
Lifecycle	7.5 (RY)	3.8 (FY06)	4.5 (RY)

Cost Growth

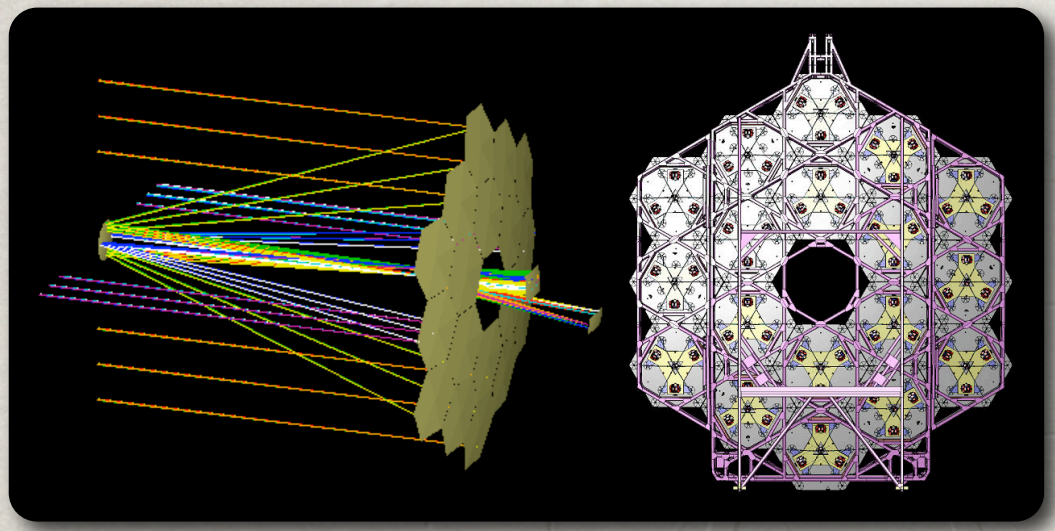
- Over the course of the formulation phase, the Project's estimate for completion of JWST has increased
  - Growth driven by both external and internal factors
- Net life cycle cost growth from $3.5B in 2004 to $4.5B in 2006
  - 30% growth ($1B)
- Majority of this increase due to external factors
  - 15% ($530M) due to 22 month launch delay:
    - Delay in approval for Ariane 5 launch vehicle
    - Fiscal year funding limitations through 2007
  - 4% ($125M) due to added contingency budget reserves
- Balance of growth due to project internal changes
  - 11% ($386M) due to changes in requirements and growth in implementation
    - Cost increases in getting major suppliers under contract
    - Architecture changes: cryocooler, ASIC control of detectors, dedicated ISIM electronics compartment, added pupil imaging lens, etc
    - I&T reevaluation: test facility changes, added launcher-related testing, NIRCam-level wavefront sensing testing, cryogenic telescope simulator for ISIM testing, etc
    - Cost growth in instruments: detectors, microshutters, etc
- Remaining cost to 2013 launch: ~$2.5B

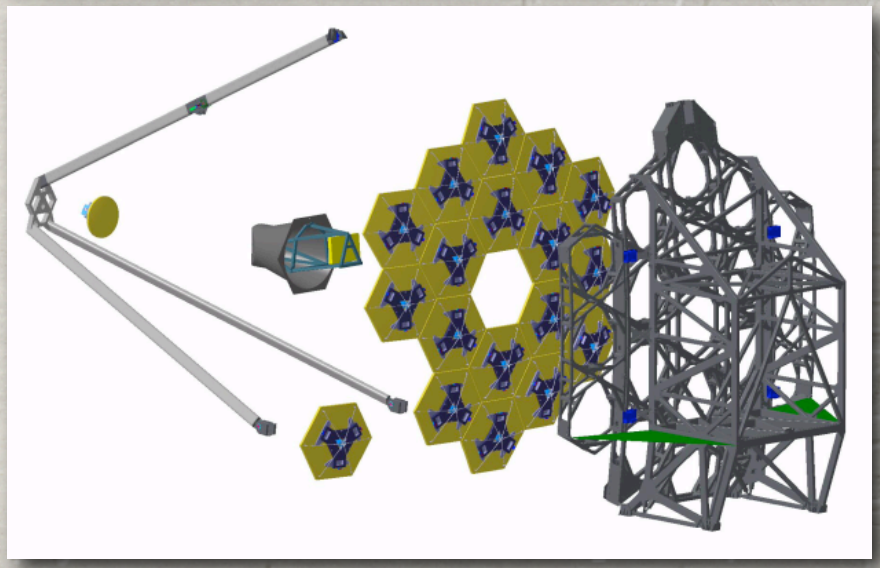


JWST Deployment: **Questions ?**



Telescope Key Elements



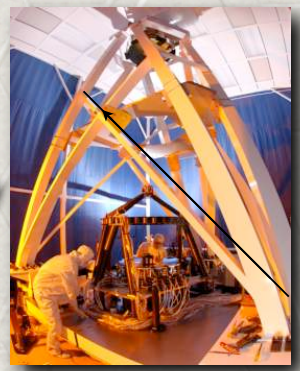


- 18 Beryllium primary mirror segments
  - deployable
- Deployable secondary mirror
- Key OTE Elements:
  - Primary mirror
  - Aft-optical system
  - Secondary mirror
  - Backplane (interface to science instruments)

JWST Test Facility Lineup

Johnson Space Flight Center Chamber A
Primary optical test facility for OTE+ISIM cryogenic thermal/optical testing. Final optical performance and WFS&C test conducted here.

Rambo (BATC)
Primary optical test facility for cryogenic testing of SMA and AOS



Test Bed Telescope (BATC)
Primary facility for development and testing of the WFS&C Algorithms

Space Environment Simulator (GSFC)
Primary optical test facility for cryogenic testing of ISIM

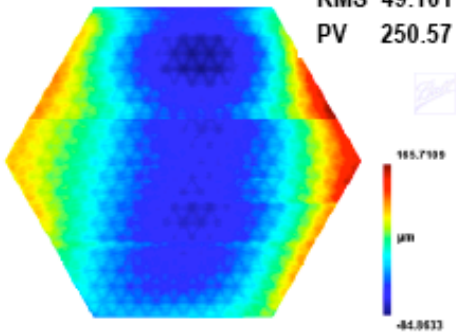
X-Ray Calibration Facility (MSFC)
Primary optical test facility for cryogenic testing of PMSAs and BSTA

Resource / Performance	Capability / Requirement	Current Estimate	Margin	Margin (%)	Comments
Performance					
Sensitivity (NIR)	11.4 nJy	9.3 nJy	2.1 nJy	22.6%	Sensitivity for NIRCam 2 micron channel
Sensitivity (MIR)	700	580 nJy	120 nJy	20.7%	Sensitivity for MIRI 10 micron channel
Wavefront Error	150 nm	144 nm	42 nm	29.2%	Margin is the "rss" difference between required and estimate
Pointing Stability	7 marcsec	6.7 marcsec	2 marcsec	29.9%	Margin is the "rss" difference between required and estimate
Observing Efficiency	70%	81%	11%	-	Efficiency based on Monograph 5 "Benchmark Mission"
Resources					
Mass	6500 kg	5311 kg	1189 kg	22.4%	Araine capability to orbit is guaranteed to be 6500 kg
Power	2079 Watts	1422 Watts	657 Watts	46.2%	Current solar arrays sized for 2079 W`at 6 years
Data Storage	471 Gbits	235 (Gbits/Day)	236 Gbits	100.4%	Margin assumes one downlink per day
Down Link Margin	3 dB	6.2 dB	3.2 dB	-	Margin assumes a Ka band data rate of 28 Mbps
Cryo Dissipation	433 mW	249 mW	184 mW	74%	Estimate is for NIRCam which currently has the min margin
Propellant	263 kg	181 kg	82 kg	45.3%	Estimate is for 5 years of on-orbit life

Pathfinder Mirror Progress

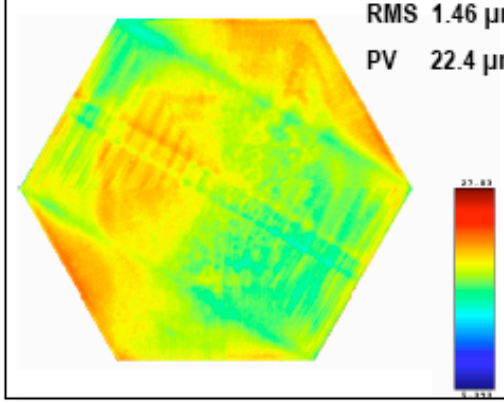
PRE CCOS PROCESSING FIGURE
1/10/2006

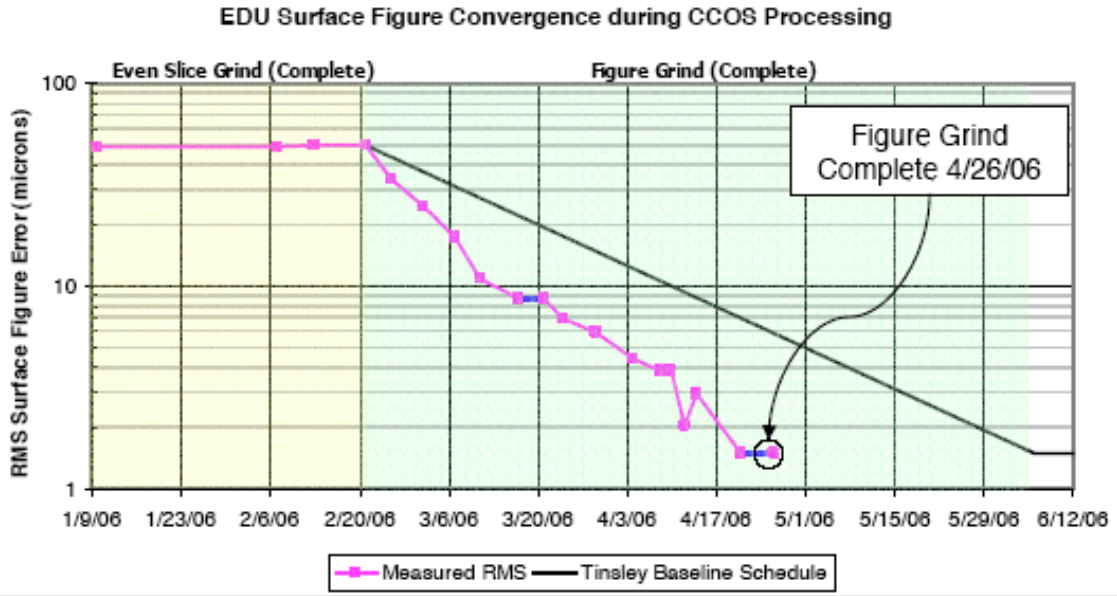
RMS 49.101 µm
PV 250.57 µm

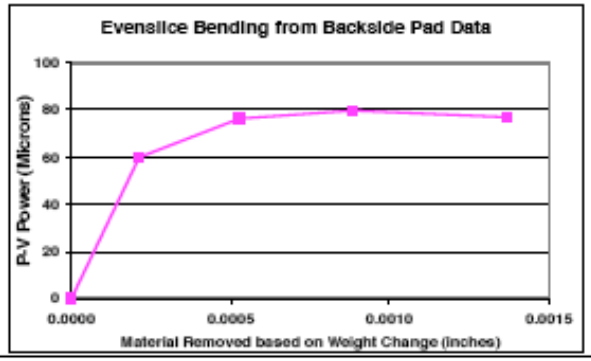


POST 15th GRIND ITERATION FIGURE
4/21/2006

RMS 1.46 µm
PV 22.4 µm







- Figure Grinding Operation converged faster than schedule baseline.
- Bending from stress flattened out during Even Slice Grinding just as predicted from Experiments after 0.0006" evenly removed.
- Segment B1 will start out the grinding process >2.5x BETTER than the EDU